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EUROPEAN PATENT APPLICATION

21 Application number: **87309692.9**

51 Int. Cl.⁴ **A61M 16/20**, **A61M 16/00**

22 Date of filing: **03.11.87**

The title of the invention has been amended
(Guidelines for Examination in the EPO, A-III,
7.3).

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30 Priority: **04.11.86 US 927243**

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43 Date of publication of application:
21.09.88 Bulletin 88/38

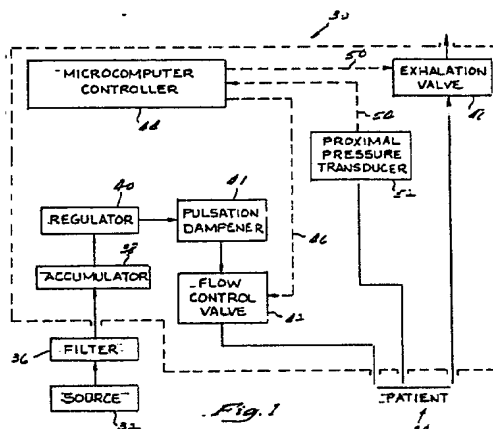
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DE FR GB IT SE

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54 **Flow control valve for a medical ventilator.**

57 A valve in a medical ventilator which controls the flow of gas from a pressurized gas source to a patient for inhalation. Flow through the valve is choked and pressure upstream of the valve is held stable so that a known relationship exists between the position of the valve and the flow rate through the valve. An open loop control system causes the valve to open or close as needed to deliver a preselected tidal volume of gas to the patient on each breath. Since the flow rate is known, no feedback to the controller regarding actual flow conditions is required. The exact positioning of the valve and length of time that the valve is to be held open is predetermined by the controller before the breath is delivered, and is repeated for subsequent breaths. Preferably, the valve is driven by a stepper motor and the controller comprises a microcomputer. The controller compensates for ramping of the stepper motor as the valve opens and closes in determining the positions of the valve required to deliver the preselected tidal volume. To ensure precise engagement between a valve member and a valve seat, the valve member is mounted on a flexible, linear wire. Additionally, a spirally wound spring surrounds a stepper motor shaft and biases the shaft so as to close the valve in the event of a power loss.

EP 0 282 675 A2



FLOW CONTROL VALVE**Background of the Invention**

5 This invention relates generally to the field of medical ventilators, and more particularly to a valve which controls the flow of gases to a patient during artificial respiration.

Medical ventilators have been developed to provide artificial respiration to patients whose breathing ability is impaired. Typically, a ventilator will deliver a breath to the patient from a pressurized source of gas. Flow to the patient during inspiration is governed by a flow control valve. When the flow control valve opens, pressurized gas is introduced to the patient's lungs. After the flow control valve closes, ending the
10 inspiration phase of the breath, the patient's respiratory gases are vented to the atmosphere through an exhalation valve, which opens after inspiration is completed and closes before the next inspiration phase begins.

Previous ventilators have been capable of operating in several modes so that the degree of support that the ventilator provides to the patient's natural breath patterns can be varied. At one extreme, the ventilator
15 can provide fully controlled ventilation in which the ventilator has complete control over when the breath is delivered and the volume of gases received by the patient during each breath. In the fully controlled mode, all of the flow parameters are preset by an operator in accordance with the particular needs of the patient. The predetermined flow parameters include the tidal volume, or the volume of gas which is inhaled by the patient during each breath; the breath rate, which is the number of breaths per minute; the peak flow rate,
20 which is the maximum flow rate of the gas delivered to the patient during inspiration; and the waveform, which is the shape of the curve in a flow rate versus time graph. The most significant of these parameters is the tidal volume, since, depending on size and age of the patient, the tidal volume can vary significantly. Thus, the fully controlled ventilation mode is often called "volume controlled" ventilation.

At the other extreme, the ventilator can be programmed to permit "spontaneous" breathing by the
25 patient. During the spontaneous breathing mode, the breath rate, the tidal volume, and other flow parameters are not predetermined. The inspiration and expiration phases of each breath are commenced in response to effort by the patient. In between the "volume controlled" and the "spontaneous breath" modes, various degrees of ventilator supported respiration are available.

One of the problems associated with previous ventilators has been that during the volume controlled
30 mode, it is extremely difficult to precisely measure the volume of flow during inspiration so as to determine when the predetermined tidal volume has been delivered, and thus at which point the flow control valve must be closed. Previous ventilators, such as that described in U.S. Patent No. 4,527,557, have utilized a microcomputer controller which receives input regarding the desired flow parameters and compare these predetermined parameters with actual flow conditions to control the opening and closing of the flow control
35 valve.

In particular, a "closed loop" control system is utilized in the ventilator disclosed in U.S. Patent No. 4,527,557, with feedback to the controller regarding the flow rate being generated by a flow transducer which is positioned downstream of the flow control valve. The actual flow rate as measured by the flow transducer is compared by the controller on a real-time basis, with the predetermined flow rate. If a
40 discrepancy exists between these two values, the valve is opened or closed accordingly. During each breath, the microcomputer controller calculates the total volume of gas delivered by incrementally summing the product of the measured flow rate and the length of the incremental time interval. When the volume calculated by the controller equals the predetermined tidal volume, the flow control valve is closed.

This system has several drawbacks, most notably being the unreliability of the flow transducer.
45 Currently available flow transducers are expensive, delicate instruments which can provide accurate flow measurements only over a narrow range of flow conditions. Further, a lag time develops between a change in actual flow rate and the system's ability to correct or compensate for the change in flow. As a result, significant differences between the predetermined tidal volume and the actual tidal volume delivered can occur.

50 Another problem with the system's closed loop servo such as that disclosed in U.S. Patent No. 4,527,557 is that the control system is complex and difficult to design so that the system is stable. On an unstable system, as the flow control valve is being opened to reach the desired peak flow rate position, flow

would be choppy and irregular as the valve overshoots the desired flow rate, and the flow rate oscillates until the valve is able to settle.

Thus, a need exists for an inexpensive ventilator which can accurately and consistently deliver a breath having a predetermined tidal volume.

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Summary of the Invention

The present invention is a ventilator which provides artificial respiration to a patient. The flow of gas to the patient during inspiration from a gas source is regulated by a flow control valve. Also provided are means for controlling the valve on an open loop basis, without requiring feedback to the control means regarding the position of the valve or the actual flow rate through the valve. Advantageously, the present open loop control system eliminates the need for a flow transducer, thus decreasing the cost of the ventilator and increasing its reliability.

Preferably, a known relationship exists between the position of the flow control valve and the rate of flow through the valve. In part, this is achieved by establishing a region of "choked" flow through the valve so that small changes in pressure downstream of the valve will not affect the flow rate through the valve. As a result, before a breath is delivered the control means can determine the required positions of the valve and the length of time that the valve must be held open in order to deliver a desired tidal volume of gas to the patient.

In a preferred embodiment, present ventilator comprises means for selecting a desired tidal volume, and means for delivering a breath at a variable flow rate to the patient. Means are also provided for calculating the length of a breath delivery period which is required in order to deliver the desired tidal volume to the patient. A feature of the invention is that the breath delivery period is calculated prior to the delivery of the breath, and then is used repeatedly in controlling the delivery of subsequent breaths to the patient. Since the length of the breath delivery period is not determined on a real-time basis, the control means can be relatively simple and inexpensive. Further, the breath delivery period is repeated for subsequent breaths, and thus the tidal volume remains consistent and accurate as identical breaths are delivered to the patient.

Another aspect of the invention is that the length of the breath delivery period is adjusted to compensate for the volume of gas that is undelivered due to the initial, non-instantaneous increase in flow rate from the closed position of the valve, and due to the extra volume of gas that is delivered due to the non-instantaneous decrease in flow rate as the valve closes. In a preferred embodiment, the flow control valve is driven by a stepper motor, and the undelivered volume of gas and the extra volume of gas result from ramp-up and ramp-down of the stepper motor as the valve is driven to the open and closed positions. By compensating for ramping of the stepper motor, the actual tidal volume delivered can be accurately correlated to the predetermined tidal volume.

The present ventilator further comprises means for generating a flow profile prior to the delivery of a breath. The flow profile is used as a pattern on which a plurality of substantially identical subsequent breaths are delivered to the patient. The flow profile is generated based on a predetermined peak flow rate and a predetermined tidal volume. Again, since the flow profile is used repeatedly, the ventilator delivers breaths of a consistent tidal volume.

In one preferred embodiment, the flow profile is translated into a sequence of steps to be carried out by the stepper motor which drives the flow control valve. A known relationship exists between each step of the stepper motor and the resulting change in flow rate. Consequently, the flow profile can be executed accurately by the valve which enables the tidal volume delivered to the patient to be precisely controlled.

The present flow control valve has several additional unique features. The valve member, which preferably is a ball, is secured to a flexible, linear wire which allows radial movement of the ball to ensure proper seating of the ball on a valve seat. This feature enables secure, sealing engagement between the ball and the valve seat despite misalignment or wear of either member. Also, the shaft of the motor which drives the valve is biased by a spring so that in the event of a malfunction, the valve is automatically closed. This prevents high pressure air from being continuously forced into the patient's lungs in the event of a power loss which would otherwise leave the valve in an open position indefinitely.

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Brief Description of the Drawings

Fig. 1 is a schematic view of the pneumatic layout of a ventilator according to one embodiment of the present invention.

Fig. 2 is a partial cross-sectional side elevation of a flow control valve according to one embodiment of the present invention.

Fig. 3A is an illustration of a rectangular breath profile;

Fig. 3B is an illustration of a tapered breath profile;

Fig. 4 is an illustration of a simplified flow profile with the intermediate portion removed of a breath with a rectangular profile;

Fig. 5 is an illustration of a simplified flow profile with the intermediate portion removed of a breath with a tapered profile; and

Fig. 6 is an illustration of three simplified, substantially identical flow profiles.

Detailed Description of a Preferred Embodiment

Referring to Figure 1, the present ventilator is shown generally at 30. The ventilator 30 receives pressurized gas, such as air or an oxygen blend, from a source 32 and controls the flow of gas to a patient 34 so as to provide artificial respiration. As will be apparent to those skilled in the art, the schematic of Figure 1 has been simplified by the elimination of various commonly used elements such as check valves, safety valves, pressure gauges, etc.

A description of the components illustrated in Figure 1, and their operation, will be understood from the following description of the flow path of gas through the ventilator 30. The gas initially passes from the source 32 through a coalescing filter 36, so as to remove both liquids and solids from the gas stream. After being filtered, the gas enters an accumulator 38 which is a rigid chamber for the temporary storage of the pressurized gas. The accumulator 38 acts as a reservoir from which gas is drawn during periods of peak demand, such as during inspiration by the patient. Downstream of the accumulator 38, a pneumatic regulator 40 is positioned. Gas flowing from the regulator 40 is maintained at a constant pressure of approximately 20 psig, which is referred to herein as the "system pressure".

System pressure gas enters a pulsation dampener 42 which, like the accumulator 38 is a rigid gas storage chamber. However, the volume of the pulsation dampener 42 is smaller than that of the accumulator 38, and the gas in the pulsation dampener 41 is at the system pressure. The pulsation dampener 41 compensates for pressure fluctuations due to the limited response time of the regulator 40 during periods when the flow rate through the regulator 40 is rapidly changing. Thus, the pulsation dampener 41 acts to maintain the system pressure constant at 20 psig.

The pulsation dampener 41 feeds gas to a flow control valve 42, the structure of which is discussed at length below. The flow control valve 42 regulates the flow rate of gas which is delivered to the patient 34 during inspiration. The flow control valve 42 can assume a plurality of positions, so as to permit various flow rates of gas to the patient 34. The position of the flow control valve 42 is controlled by a microcomputer controller 44. An electronic signal 46 is sent by the controller 44 to cause opening or closing of the valve 42. As is discussed in greater detail below, the controller 44 does not utilize feedback regarding flow conditions downstream of the valve 42 in order to determine what the proper position of the valve 42 should be. Thus, the valve 42 is controlled on an "open loop" basis.

Although not shown the patient 34 is fitted with an endotracheal tube which establishes fluid communication between the patient's lungs and the ventilator 30. As is well known, the endotracheal tube is inserted in the patient's trachea or wind pipe, and is surrounded by a balloon which forms a seal with the trachea so that all gas flow into and out of the lungs takes place through the endotracheal tube, which is in fluid communication with the flow control valve 42.

An exhalation valve 48 is provided to establish fluid communication between the patient's lungs and the atmosphere. When open, the exhalation valve 48 permits the patient 34 to exhale by venting respiratory gases to the atmosphere through the endotracheal tube. Opening and closing of the exhalation valve 48 is governed by the controller 44, which sends an electronic signal 50 to the exhalation valve 48 to effect a change in the position of the exhalation valve 48. The controller 44 determines the proper position of the exhalation valve 48 based on feedback from a proximal pressure transducer 52. The proximal pressure transducer 52 measures the pressure of the gas on the ventilator side of the seal formed by the endotracheal tube, which is referred to as the "proximal" gas. Feedback to the controller 44 is in the form of an input signal 54 from the proximal pressure transducer 52, which is an electrical analog of the proximal

pressure.

When the ventilator 30 is operating in a fully controlled mode, in which the patient 34 has no control over the flow parameters, inspiration begins when the flow control valve 42 is signalled to open by the controller 44. Opening of the flow control valve 42 causes gas to enter the patient's lungs through the endotracheal tube. The exhalation valve 48 remains closed during inspiration so that the gas in the endotracheal tube does not leak to the atmosphere. When the flow control valve 42 closes on command from the controller 44, the inspiration phase of the breath terminates.

The expiration phase is commenced by the opening of the exhalation valve 48, the timing of which is determined by the controller 44. Upon opening of the exhalation valve 48, gas within the patient's lungs is automatically expelled to the atmosphere. The exhalation valve 48 closes after the patient 34 has finished exhaling. The ventilator 30 includes a positive expiration end pressure (PEEP) feature so that an operator can preset what the pressure level of the proximal gases should be at the end of each breath. During expiration, the controller 44 compares the actual proximal pressure to the predetermined pressure level (PEEP) and when the proximal pressure reaches the predetermined level, the controller 44 sends a signal 50 to cause the valve 48 to approach the closed position. The controller then "servos", or controls the position of the valve 48 on a closed loop basis so as to maintain the actual proximal pressure equal to the predetermined pressure. After the exhalation valve 48 is completely closed, the flow control valve 42 opens to end the expiration phase and begin the next inspiration phase. This cycle is repeated continuously to establish artificial respiration.

Turning now to Figure 2, the flow control valve 42 is shown in greater detail. Gas from the accumulator 38 enters the flow control valve 42 through an inlet passageway 56 in a valve housing 58. Gas leaves the flow control valve 42 on the way to the patient 34 through an outlet passageway 60 in the housing 58. Between the inlet 56 and the outlet 60, a valve seat 62 is positioned. An orifice 64 extends through the valve seat 62, and permits gas to flow from the inlet 56 to the outlet 60. The orifice 64 has a converging, frusto-conical nozzle portion 66 on the side of the inlet 56, and a diverging, frusto-conical nozzle portion 68 on the side of the outlet 60.

A spherical valve member or ball 72 rests within the divergent portion 68 of the valve seat 62. The valve 42 is shown in the closed position, with the outer surface of the ball 72 in sealing engagement with the valve seat 62, so as to prevent flow through the orifice 62. The various positions of the valve 42, and the various flow rates through the valve 42, are caused by displacement of the ball 72 relative to the valve seat 62. This changes the area of the orifice 64 through which gas flow is permitted, and thus the rate of flow through the valve 42. A substantially linear relationship exists between the orifice area through which gas flows and the displacement of the ball 72.

The position of the valve 42 is changed by means of a stepper motor 74. The stepper motor 74 receives electronic signals 46 from the controller 44 which causes rotation of a stepper motor shaft 76. On the end of the shaft 76, a cam 78 is mounted. The cam 78 includes an axially facing cam surface 80. A cam follower or roller 82 is biased into engagement with the cam surface 80 by a spring 84. Thus, rotation of the shaft 76 and the cam 78 causes displacement of the roller 82 as the roller 82 follows the pitch of the cam surface 80.

Displacement of the roller 82 is translated to the ball 72 by means of an elongated, cylindrical stem 86. The stem 86 is slidable along a linear axis of motion either toward or away from the valve seat 62. The roller 82 is rotatably mounted at one end of the stem 86. At the other end of the stem 86, the ball 72 is secured to the stem 86 by means of an elongated flexible wire 88, which is preferably formed from stainless steel and has a diameter of approximately thirty-five thousandths of an inch.

The longitudinal axis of the wire 88 is substantially parallel to the linear axis of motion of the wire 88 and the stem 86. The flexibility of the wire 88 permits the wire 88 to deviate from the axis of motion, resulting in radial displacement of the ball 72. During operation of the valve 42, the ball 72 and the valve seat 62 often become misaligned, or due to wear of either element, the radial position of the ball 72 must be changed in order to effect a tight sealing engagement between the ball 72 and the valve seat 62. Advantageously, the wire 88 automatically permits adjustments in the radial position of the ball 72 to compensate for such misalignment or wear.

The valve body 62 is surrounded by a pair of resilient O-rings 90 which forms a seal between the valve seat 62 and the surrounding housing 58. To prevent damage to the ball 72 and seat 62 in the event of overshooting of the stem 86 past the closed position of the valve 42, compression of the O-rings 90 permits movement of the valve seat 62.

A spirally wound spring 94 formed from a thin metallic strip surrounds the stepper motor shaft 76. The spring 94 biases the shaft 76 to rotate in a direction which causes the valve 42 to close. During normal operation, the stepper motor 74 overcomes the biasing torque generated by the spring 94 so that the spring

94 does not affect the position of the valve 42. However, in the event of a power loss, the spring 94 automatically biases the valve 42 to a closed position. This prevents a stream of system pressure gas from constantly being forced into the patient's lungs in the event of such an emergency. Although not shown in the drawings, the ventilator 30 includes a safety valve so that the patient would be allowed to breathe ambient air after the flow control valve 42 was biased closed.

Due to the structure of the flow control valve 42, the stable pressure conditions upstream of the valve 42 and the flow conditions established within the valve seat 62, a known relationship exists between the position of the ball 72 and the flow rate of gas through the valve 42. Each step of the stepper motor 74 causes a certain amount of displacement of the ball 72, which is in turn correlated to a known change in flow rate. This relationship exists for all flow conditions in the valve 42 during operation of the ventilator 30.

The major reason why flow through the valve 42 is so predictable is because a region of "sonic" or "choked" flow is established within the valve seat 62. As is well known, choked flow occurs when the ratio of the absolute pressure downstream of a nozzle or orifice relative to the absolute pressure upstream of the orifice is 0.528 or less. The significance of the choked flow condition is that variations in pressure downstream of the orifice which do not cause the 0.528 ratio to be exceeded will not change the rate of flow through the orifice. Thus, if the downstream and upstream pressures are maintained at the .528 ratio or below, a change in orifice area can be precisely correlated to the resulting change in flow rate, regardless of the downstream flow conditions.

In the present ventilator 30, the pressure upstream of the orifice 64 is maintained at a constant 20 psig, or approximately 34.7 psia. Enough gas is stored in the accumulator 38 during expiration so that during the inspiration phase of each breath, the flow rate to the patient 34 can exceed the flow rate of gas into the accumulator 38 from the source 32. The pulsation dampener 41 acts as a buffer between the regulator 40 and the flow control valve 42 so as to maintain the pressure upstream of the valve 42 at a constant 20 psig. The flow control valve 42 is capable of causing very fast changes in the gas flow rate which in turn forces the regulator 40 to respond rapidly in order to maintain a constant system pressure. During these transient flow conditions, pressure fluctuations occur due to the limited response time of the regulator 40. The pulsation dampener 41 stores a small quantity of gas to minimize these pressure fluctuations.

Downstream of the orifice 64, the pressure is a function of the resistance to flow through the patient's airways and the resilience or "compliance" of the patient's lungs. The less compliant the lungs are, the more pressure will be developed in the lungs when filled with a given volume of gas. It has been found that in adults with the least compliant lungs, the maximum back pressure which is desirable to establish within the lungs during normal ventilation is about 2 psig. Thus, the pressure downstream of the orifice 64 is always approximately 16.7 psia or less. The maximum ratio of absolute pressures then is 16.7 psia/34.7 psia, or about 0.48, which is less than the 0.528 maximum ratio required to maintain choked flow.

Due to the establishment of choked flow within the valve 42 during operating conditions, the known and constant pressure level upstream of the valve 42, and the linear relationship which exists between displacement of the ball 72 and the area of the orifice 64, the flow rate is known for all positions of the valve 42. Since the valve 42 is moved in discrete, incremental steps by the stepper motor 74, the relationship is known between the change in flow rate for each step of the stepper motor 74. As is discussed in greater detail below, since the controller 44 can keep track of the position of the valve 42, the flow rate is known to the controller 44 due to the known relationship between valve positions and flow rate. As a result, the controller 44 can control the valve 42 on an open loop basis.

OPERATION

In one mode of operation, the ventilator 30 completely controls the patient's breathing. In this mode, which is usually used for severely incapacitated or unconscious patients, the patient's breath rate, the volume of air per breath (tidal volume), and the flow rate at which air is delivered are all controlled by the ventilator 30.

The ventilator 30 includes a number of switches (not shown) which enable an operator to select the desired characteristics of this completely controlled ventilation provided to the patient 34. These characteristics include the peak flow rate, the tidal volume, and the breath rate. The breath rate is the desired number of breaths per minute. The tidal volume is the total volume of gas delivered to the patient during each breath. The peak flow rate is the maximum rate of gas flow at which each breath is delivered.

The operator may also select the breath profile. The breath profile is defined as the desired rate of flow delivered to a patient versus time. A rectangular breath profile 10 and a tapered breath profile 12 are illustrated in Figs. 3A and 3B, respectively. For the rectangular breath profile 10, the desired flow

instantaneously increases from zero to the peak flow rate at time t_i and instantaneously decreases from the peak flow rate to zero at time t_r . For the tapered breath profile 12, the desired flow increases instantaneously at time t_i to the peak flow rate and gradually decreases along a straight line to one-half of the peak flow rate at time t_r , at which point the flow instantaneously decreases to zero.

5 No ventilator can deliver a breath exactly in accordance with these breath profiles 10, 12 since no ventilator can instantaneously change the flow rate from zero to the peak flow rate, and vice versa. However, ventilators deliver flow profiles which approximate the idealized breath profiles 10, 12. A flow profile is defined as the actual rate of flow delivered to a patient versus time. Figs. 4, 5 and 6 illustrate a number of flow profiles 14, 16, 18. In Figs. 4 and 6, the illustrated flow profiles 14, 18 correspond to breaths
10 having rectangular breath profiles, while the flow profile 16 in Fig. 5 corresponds to a breath having a tapered breath profile. The flow profiles 14, 16, 18 have been significantly simplified and are presented in such simplified form for purposes of clarity in the explanation of the ventilator operation.

After the ventilation characteristics have been selected by the operator but prior to ventilating the patient 34, the ventilator 30 determines what the flow profile of a plurality of breaths will be, based upon the
15 selected characteristics, and uses the flow profile to control the delivery of ventilation to the patient 34.

In determining this flow profile, the controller 44 initially determines the number of steps through which the stepper motor 74 must be displaced to provide the discrete flow rate which most closely corresponds to the peak flow rate selected by the operator. As discussed above, the ventilator flow control valve 42 is capable of delivering many discrete flow rates. As a result, although the flow rate selected by the operator
20 may not exactly equal one of the discrete flow rates providable by the flow control valve 42, any difference would be quite small since the flow control valve 42 is capable of delivering many discrete flow rates.

The number of steps required to provide the discrete flow rate which most closely corresponds to the selected peak flow rate is determined in accordance with the following equation:

$$\text{STEPS} = \text{INTEGER} [\text{FLOWRATE}/\text{VALVRATE} + 0.5] + \text{CONSTANT}, \quad (1)$$

25 where FLOWRATE is the selected peak flow rate, VALVRATE is a constant which represents the incremental flow of gas through the valve 42 per step, INTEGER is the truncation function, which truncates any fraction of the operand, CONSTANT represents a predetermined number of steps necessary to compensate for a nonlinear portion of the flow control valve near its closed position, and STEPS is the required number of steps corresponding to the discrete flow rate closest to the selected peak flow rate.

30 The INTEGER function is used since the stepper motor 74 can only be displaced through a whole number of steps. The 0.5 which is added to the value of FLOWRATE/VALVRATE before truncation by the INTEGER function compensates for the fact that the INTEGER function truncates instead of rounding to the nearest whole number.

In the particular flow control valve 42 used in this described embodiment, VALVRATE is 1.000 liter per minute per step and CONSTANT is 3. Where different flow control valves are used, VALVRATE and
35 CONSTANT may have different values.

Equation (1) assumes that the relationship between the actual flow of gas through the flow control valve 42 and the number of steps is linear. A linear flow control valve is one that delivers additional increments of flow that are equal; that is, each further incremental opening of the valve delivers the same amount of
40 additional flow. Even though a flow control valve may be nonlinear, such a valve may still deliver a precise or known amount of flow at each incremental opening. Such a nonlinear valve could be used in connection with this embodiment.

If a nonlinear valve is used, instead of using Equation (1), a software lookup table is provided in order to derive the number of steps corresponding to the discrete flow rate closest to the selected peak flow rate.
45 Such a software lookup table includes the actual flow rate that is delivered at each incremental opening of the flow control valve so that the actual flow rate most closely corresponding to the selected peak flow rate can be retrieved from the table along with the corresponding number of steps.

After determining the number of steps necessary to provide the closest discrete flow, the actual flow rate is determined so that the actual tidal volume delivered to the patient 34 may be made equal to the tidal
50 volume selected by the operator.

In order to calculate the actual flow from the number of steps determined in accordance with Equation (1), the following equation is used where the flow is linear with the number of steps:

$$\text{FLOW} = (\text{STEPS} - \text{CONSTANT}) \times (\text{VALVRATE}), \quad (2)$$

55 where STEPS is the number of steps that was calculated in Equation (1) which would yield the actual discrete flow closest to the desired peak flow, CONSTANT is the number used to compensate for a nonlinear portion of the flow control valve, VALVRATE is the constant which represents the incremental flow through the valve 42 per step, and FLOW is the actual flow delivered.

If the flow rate provided by the flow control valve 42 is not linear with the number of steps, the software

lookup table described above can be used to provide the actual flow from the number of steps. In this case, instead of just comparing the selected peak flow rate with each of the discrete actual flow rates and only retrieving the number of steps corresponding to the closest actual flow rate, the actual flow rate is retrieved as well.

5 After the number of steps and the corresponding actual peak flow rate are determined, the controller 44 determines a breath delivery period which determines the length of time that a breath is delivered to the patient 34. In general, a breath delivery period is broadly defined as any period of time which is used to determine how long the duration of a breath should be. While a breath delivery period is defined broadly, one particular definition is set forth below to aid in the explanation of the ventilator 30 of the described
10 embodiment.

An important feature of the ventilator 30 is directed to the delivery to the patient 34 of an actual tidal volume which is substantially equal to the tidal volume preselected by the operator. The delivery of such a precise actual tidal volume is accomplished by adjusting the magnitude of the breath delivery period.

One simplified method of determining the breath delivery period necessary to deliver the tidal volume
15 selected by the operator would be to divide the preselected tidal volume by the actual peak flow rate determined in accordance with Equation (1). This simplified method assumes that the flow rate is instantaneously increased to the peak flow rate at the beginning of a breath and instantaneously decreased at the end of a breath. However, since a flow control valve 42 cannot be opened instantaneously, the actual volume delivered during the initial portion of the breath is somewhat less than the amount expected by the
20 idealized method. This volumetric difference is referred to as the undelivered volume that would be lost during the increase of the flow rate during the initial portion of the breath. Also, since the flow control valve 42 is not closed instantaneously at the end of a breath, there is an extra volume delivered that is not taken into account by the simplified method. In Fig. 4, the undelivered volume that would be lost corresponds to the area 20 bounded by the dotted line and the extra volume that would be delivered corresponds to the
25 area 22 bounded by the dotted line. Since the flow control valve 42 may not be opened and closed at identical rates, the undelivered volume lost may not be equal to the extra volume delivered, so that the actual volume delivered will not equal the preselected tidal volume. In order to account for this volumetric error, the controller 44 adjusts the breath delivery period so that the actual volume delivered is substantially equal to the preselected tidal volume.

30 For purposes of the following discussion, a breath delivery period is defined as including the initial portion of a breath during which the flow rate is rapidly increasing and the intermediate portion of the breath just prior to the rapid decrease of flow during the final portion of the breath, but excluding this final portion of the breath. Thus, in Figs. 4 and 5, the breath delivery period starts at time t_i and ends at time t_q . The breath delivery period is precisely defined in this manner only for purposes of explanation of the ventilator's
35 operation.

The breath delivery period is determined in accordance with the following equation:

$$\text{BDP} = (V_X + \text{VOLUME} - V_Y) / \text{FLOW}, \quad (3)$$

where V_X is the undelivered volume that would be lost while the valve is opening, V_Y is the extra volume that would be delivered while the valve is closing, VOLUME is the selected tidal volume, FLOW is the actual
40 flow rate closest to the preselected flow rate, and BDP is the breath delivery period.

Thus, as it can be seen from Equation (3), if the undelivered volume that would be lost, V_X , is larger than the extra volume that would be delivered, V_Y , the breath delivery period is increased to account for this difference. If the undelivered volume lost, V_X , is less than the extra volume delivered, V_Y , the breath delivery period is shortened to accommodate this difference. If it happens that the extra volume delivered is exactly
45 equal to the undelivered volume lost, then the breath delivery period is unaffected. Thus, the adjustment of the breath delivery period in this manner ensures that the actual volume delivered will substantially equal the preselected tidal volume.

The undelivered volume lost and the extra volume delivered, which are stored in a software lookup table, can be computed as a summation of time-flow products, a time-flow product being defined as a
50 volume computed as the product of the actual flow delivered at one of the incremental openings of the flow control valve and the length of time the valve is opened to that incremental opening. More particularly, the undelivered volume that would be lost is determined in accordance with the following equation:

$$55 \quad V_X = \sum_{n=1}^P (\text{FLOW} - A_n) \times (t_n), \quad (4)$$

where FLOW is the actual peak flow, A_n is the actual flow delivered by the flow control valve in its n th

incremental position, t_n is the amount of time that the flow control valve is in the n th position, and V_x is the undelivered volume lost.

The extra volume that would be delivered during the closing of the flow control valve 42 is determined in accordance with the following equation:

$$V_Y = \sum_{n=q}^f (A_n) \times (t_n), \quad (5)$$

where A_n is the actual flow delivered by the flow control valve in its n th incremental position, t_n is the amount of time the flow control valve 42 is in the n th position, and V_Y is the extra volume delivered while the flow control valve 42 is closing during the final portion of a breath.

Instead of computing the extra volume delivered and undelivered volume lost as the summation of a plurality of time flow products, these volumes can also be determined empirically by direct volumetric measurement. Regardless of how they are determined, these volumes are stored in a software lookup table which provides the total cumulative undelivered volume lost and the extra volume delivered for each actual peak flow position of the flow control valve.

The controller 44 also includes conventional ramp-up and ramp-down profiles for the flow control valve stepper motor. The ramp-up profile for the stepper motor 74 determines the rate at which the motor 74 accelerates, and the ramp-down profile determines the rate at which the motor decelerates. Each of the ramp profiles essentially comprises a series of time delays which govern the rate at which the stepper motor is energized. Seven different sets of ramp-up and ramp-down profiles are provided. One of the seven sets is selected to drive the stepper motor 74 depending upon (1) the direction in which the flow control valve 42 is being moved, opened or closed, and (2) the number of steps through which the stepper motor 74 must be displaced to move the flow control valve 42 to its desired position. Different ramp profile sets are provided based upon direction because the flow control valve 42 is spring-biased closed, as described above, which affects the rates at which the stepper motor 74 can be accelerated and decelerated. Thus, if the valve 42 is being opened, the stepper motor 74 must be accelerated more slowly since it must overcome the force of the spring 84 while if the valve is being closed, the stepper motor 74 can be accelerated more rapidly. Different ramp profile sets are provided based on the number of steps in order to minimize the travel time of the stepper motor 74. For example, if the desired valve position is 100 steps away from the current valve position, a particular ramp profile set is used. If the desired valve position is only 20 steps away, a different ramp profile set is used. The ramp profiles are developed in a conventional well-known manner, and the particular time delays contained in the ramp profiles depend upon the stepper motor 74 used and the mass and friction of the coupling between the stepper motor 74 and the flow control valve 42, in addition to direction and distance as described above. The seven sets of ramp profiles, which include a total of fourteen ramp profiles in all, are listed in Appendix A.

The ventilator uses the stepper motor ramp profiles, the breath delivery period, and the number of steps required to deliver the discrete flow rate closest to the selected peak flow rate to delivery each of a plurality of breaths to a patient. Since each breath is based upon the same predetermined ramp profiles, breath delivery period, and number of steps, each breath has a substantially identical flow profile. In addition, the tidal volume of each breath is substantially identical to the preselected tidal volume since the breath delivery period is adjusted to compensate for the variability of the flow rate.

Referring now to Fig. 4, in delivering a breath with a rectangular profile the ventilator selects a particular ramp profile set consisting of a ramp-up profile and a ramp-down profile. Then, the ventilator accelerates the stepper motor 74 in accordance with the selected ramp-up profile to start delivering flow at time t_i . The stepper motor 74 is decelerated in accordance with the selected ramp-down profile until the stepper motor 74 reaches at time t_p the step predetermined in Equation (1) corresponding to the discrete flow closest to the selected peak flow. The flow remains substantially constant until a later time t_q at which point the stepper motor 74 is stepped in accordance with the ramp profiles to gradually close the flow control valve until it is completely closed at time t_r . More specifically, at time t_q , the stepper motor 74 is accelerated in accordance with the selected ramp-up profile, which is different than the profile used to open the valve 42 at time t_i , since the direction is different. The stepper motor 74 is then decelerated in accordance with the selected ramp-down profile, which is also different since the valve direction has changed, until the valve 42 completely closes at time t_r .

The ventilator 30, when desired, also delivers breaths with a tapered breath profile. Referring now to Fig. 5, a breath having this profile is delivered by rapidly increasing the flow from zero to a peak flow rate,

gradually decreasing the peak flow rate to one-half of the peak flow rate, and then rapidly decreasing the flow rate back to zero during the final portion of the breath. The flow profile 16 shown in Fig. 5 is a piece-wise linear approximation of the tapered breath profile 12 in Fig. 3B.

The delivery of a plurality of breaths having tapered profiles requires several additional preliminary steps than those needed to deliver a plurality of breaths with a rectangular profile. First, the breath delivery period must be adjusted for the tapered profile. More particularly, after the ventilator has determined the number of steps necessary to provide the discrete flow closest to the selected peak flow and the breath delivery period as described above, if the breath is to have a tapered profile, the controller 44 increases the breath delivery period by one-third in order to accommodate for the gradual decrease of the peak flow rate at the start of a breath to one-half of the peak flow rate at the end of a breath. Referring now to Fig. 3B, it can be seen that the tidal volume delivered in a breath with a tapered profile is less than the tidal volume of a breath with a rectangular profile having an equal duration by an area equal to the dotted area 24. This dotted area 24 is equal to one-third of the area 26 underneath the breath profile 12. Thus, in order to provide the tapered profile 12 and yet still deliver the same tidal volume, the breath delivery period is increased by one-third for breaths with a tapered profile.

In addition to increasing the breath delivery period, the controller 44 performs several other steps in order to deliver a breath with a tapered profile. The controller 44 determines the number of steps required to deliver one-half the peak flow rate by dividing the value of STEPS determined in Equation (1) by two.

During the gradual decrease of the flow rate from the peak flow rate to one-half of the peak flow rate during the intermediate portion of the breath, the controller 44 closes the flow control valve 42 by one step each time a predetermined time interval elapses. Thus, the number of time intervals required to gradually decrease the flow from the peak flow rate to one-half the peak flow rate equals the number of steps required to accomplish the same.

Each time interval has an equal duration which is determined by dividing the increased breath delivery period for the tapered profile by the number of steps required to move the flow control valve 42 from its peak flow position to one-half of the peak flow position. After the duration of the time intervals is calculated, the ventilator 30 may deliver breaths with a tapered profile.

Now referring to Fig. 5, the flow profile 16 is delivered by rapidly increasing the flow rate at an initial time t_i to a peak flow rate at a later time t_p , gradually decreasing the flowrate during the intermediate portion of the breath to one-half of the peak flow rate at time t_q , and then rapidly decreasing the flow rate to zero at a time t_r . The gradual decrease of the flow rate from the peak flow rate to one-half of the peak flow rate during the intermediate portion of the breath is accomplished by closing the flow control valve 42 one step as each of the intervals described above elapses. More particularly, as soon as the flow rate reaches the peak flow rate at the time t_p , the ventilator waits one-half of an interval after the time t_p before closing the flow control valve by one step. Thereafter, as each full interval elapses, the flow control valve 42 is closed by one step until the flow rate decreases to one-half of the peak flow rate, at which time the controller 44 waits one-half of an interval before rapidly closing the flow control valve 42 to end the breath.

Upon completing the delivery of a single breath of either profile, the ventilator 30 waits a predetermined period of time based upon the preselected breath rate before delivering another breath. Each subsequent breath delivered by the ventilator 30 is also based upon the same peak flow rate, actual flow rate, breath delivery period, and ramp profiles used to deliver the initial breath, all of which were calculated prior to the delivery of the breaths. Thus, each of the breaths has the same flow profile, and the breaths are substantially identical, and have substantially identical tidal volumes, as is illustrated in Fig. 6.

Claims

1. A method of delivering a plurality of substantially identical breaths to a patient whose breathing ability is impaired by determining what the flow profile of a plurality of breaths will be prior to the delivery of the breaths, said method comprising:

- (a) determining what the flow profile of a breath will be prior to the delivery of a plurality of breaths, said flow profile being determined based upon a desired peak flow rate and a desired tidal volume; and
- (b) delivering a plurality of breaths to a patient, each of said breaths being substantially identical.

2. A method as defined in Claim 1, wherein said determining what the flow profile in step (a) will be comprises preparing a ramp-up profile for the initial portion of a breath whereby the breath flow rate increases from zero to a peak flow rate when said ramp-up profile is used to deliver a breath in said step (b).

3. A method as defined in Claim 2, wherein said determining what the flow profile will be additionally comprises preparing a ramp-down profile for the final portion of a breath whereby the breath flow rate decreases from a peak flow rate to zero when said ramp-down profile is used to deliver a breath in said step (b).

5 4. A method as defined in Claim 3, wherein said ramp-up profile comprises a plurality of predetermined time delays which control the incremental opening of a flow control valve, and said ramp-down profile comprises a plurality of predetermined time delays which control the incremental closing of a flow control valve.

10 5. A method as defined in Claim 4, wherein said determining what the flow profile will be additionally comprises determining a breath delivery period which determines what the tidal volume of a breath will be.

6. A ventilator (30) for delivering a plurality of substantially identical breaths to a patient whose breathing ability is impaired by determining what the flow profile of a plurality of breaths will be prior to the delivery of the breaths, said ventilator comprising:

15 means (44) for determining what the flow profile of a plurality of breaths will be prior to the delivery of the breaths, said flow profile being predetermined based upon a desired peak flow rate and a desired tidal volume;

means (42) for delivering a breath at an incrementally variable flow rate; and

means (44, 46) coupled to said breath delivering means for delivering a plurality of breaths to a patient, each of said breaths having a substantially identical flow profile.

20 7. A ventilator (30) which provides artificial respiration to a patient from a pressurized source of gas, said ventilator comprising:

a flow control valve (42) which controls the flow of gas to the patient from the source (32) of gas, said valve (42) being movable to a plurality of positions so as to permit various flow rates of gas to the patient; and open loop control means (44, 46) for controlling the position of said valve (42), said control means (44, 46) 25 generating command signals which cause opening or closing of said valve (42) without requiring feedback regarding the position of said valve (42) or the actual flow rate of gas through said valve (42).

8. The ventilator of Claim 7, wherein said control means (44, 46) causes said valve (42) to deliver breaths to the patient according to a predetermined rate of breaths per minute.

30 9. The ventilator of Claim 8, wherein said control means (44, 46) causes said valve (42) to deliver breaths to the patient according to a predetermined flow rate versus time waveform.

10. The ventilator of Claim 7, wherein a known relationship exists between the position of said valve (42) and the flow rate of gas through said valve (42).

11. The ventilator of Claim 10, wherein flow through said valve (42) is choked.

12. The ventilator of Claim 10, wherein said control means (44, 46) causes said valve (42) to deliver a 35 predetermined tidal volume of gas to the patient during each breath.

13. The ventilator of Claim 12, wherein said control means (44, 46) determines the position of said valve (42) required to deliver said predetermined tidal volume prior to the delivery of a breath to the patient.

14. The ventilator of Claim 7, wherein said valve (42) comprises:

40 a stepper motor (74) having a rotatable shaft (76), said stepper motor (74) causing rotation of said shaft (76) in response to said command signal;

a valve seat (62) having an orifice therein, said respiratory gas flowing through said orifice;

a ball (72) which mates with said seat (62), movement of said ball (72) relative to said seat (62) causing the area of said orifice to vary, thus causing the flow rate of gas through said orifice to vary; and

means for translating rotation of said shaft (76) into movement of said ball (72) relative to said seat (62).

45 15. The ventilator of Claim 14, wherein said translating means comprises:

a cam (78) mounted on said shaft (76), said cam (78) having an axially facing cam surface (80);

a cam follower (82) which engages said cam surface (80) and which is displaced axially relative to said shaft (76) upon rotation of said shaft (76); and

50 an elongated, linear wire (88) which is jointed at one end to said ball (72) and at another end to said cam follower (82), said wire (88) being flexible to cause radial displacement of said ball (72) and permit sealing engagement between said ball (72) and said seat (62) despite misalignment or wear.

16. The ventilator of Claim 14, wherein said valve (42) further comprises a spring (94) for biasing said valve (42) into a closed position in the event of an emergency, said spring (94) causing rotation of said shaft (76), said stepper motor (74) overcoming the biasing force of said spring (94) during normal operation.

55 17. The ventilator of Claim 16, wherein said spring (94) is formed of a thin strip of spirally-wound material, said spring (94) surrounding said shaft (76).

18. A valve (42), comprising:

a valve seat (62) which surrounds an orifice through which fluid passes;

a valve member (72) which engages said valve seat (62) to prevent flow through said orifice;

5 means (74, 78, 82) for displacing said valve member (72) relative to said valve seat (62) so as to vary the flow rate of fluid through said valve (42); and

an elongated, linear wire (88) joined at one end to said valve member (72) and at another end to said displacing means (74, 78, 82), said wire having a longitudinal axis, said displacing means (74, 78, 82) causing said wire (88) to move substantially parallel to said longitudinal axis, wherein said wire (88) is flexible and permits radial movement of said valve member (72) relative to said seat (62) so as to
10 compensate for misalignment of said valve member (72) and said seat (62).

19. The valve of Claim 18, wherein said displacing means comprises:

a stepper motor (74) having a rotatable shaft (76);

a cam (78) mounted on said shaft (76); and

15 a cam follower (82) which engages said cam rotation of said cam (78) causing displacement of said cam follower (82), said wire (88) being joined at one end to said cam follower (82).

20. The valve of Claim 18, wherein said wire (88) has a diameter of approximately thirty-five thousandths of an inch.

21. The valve of Claim 18, wherein said valve member (72) comprises a ball (72).

22. A valve (42), comprising:

20 a valve seat (62) having an orifice through which fluid passes;

a valve member (72) which is movable relative to said valve seat (62) to vary flow through said orifice;

a motor (74) having a shaft (76), motion of said shaft (76) causing movement of said valve member (72) relative to said valve seat (62); and

25 a spring (94) which engages said shaft (76) so that, in the event of a power loss to said motor (74), said shaft (76) is biased by said spring (94) to cause said valve to assume either an open position or a closed position, said motor (74) overcoming the force of said spring (94) during normal operation.

23. The valve of Claim 22, wherein rotation of said shaft (76) causes movement of said valve member (72), and wherein said spring (94) is spirally-wound around said shaft (76).

24. The valve of Claim 22, wherein said motor (74) comprises an electrically powered stepper motor
30 (74).

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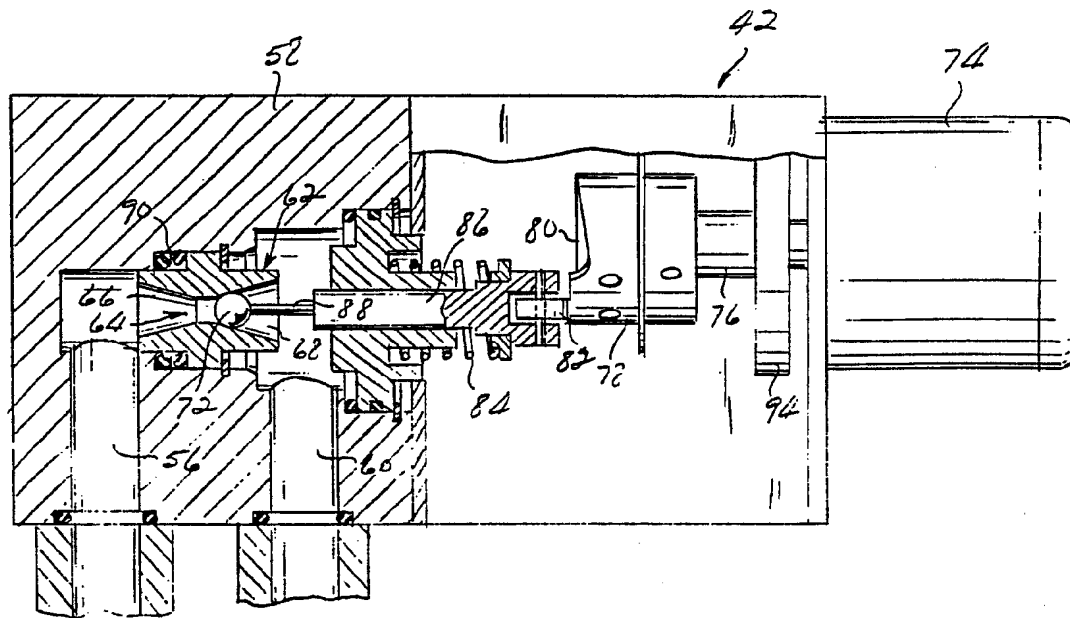
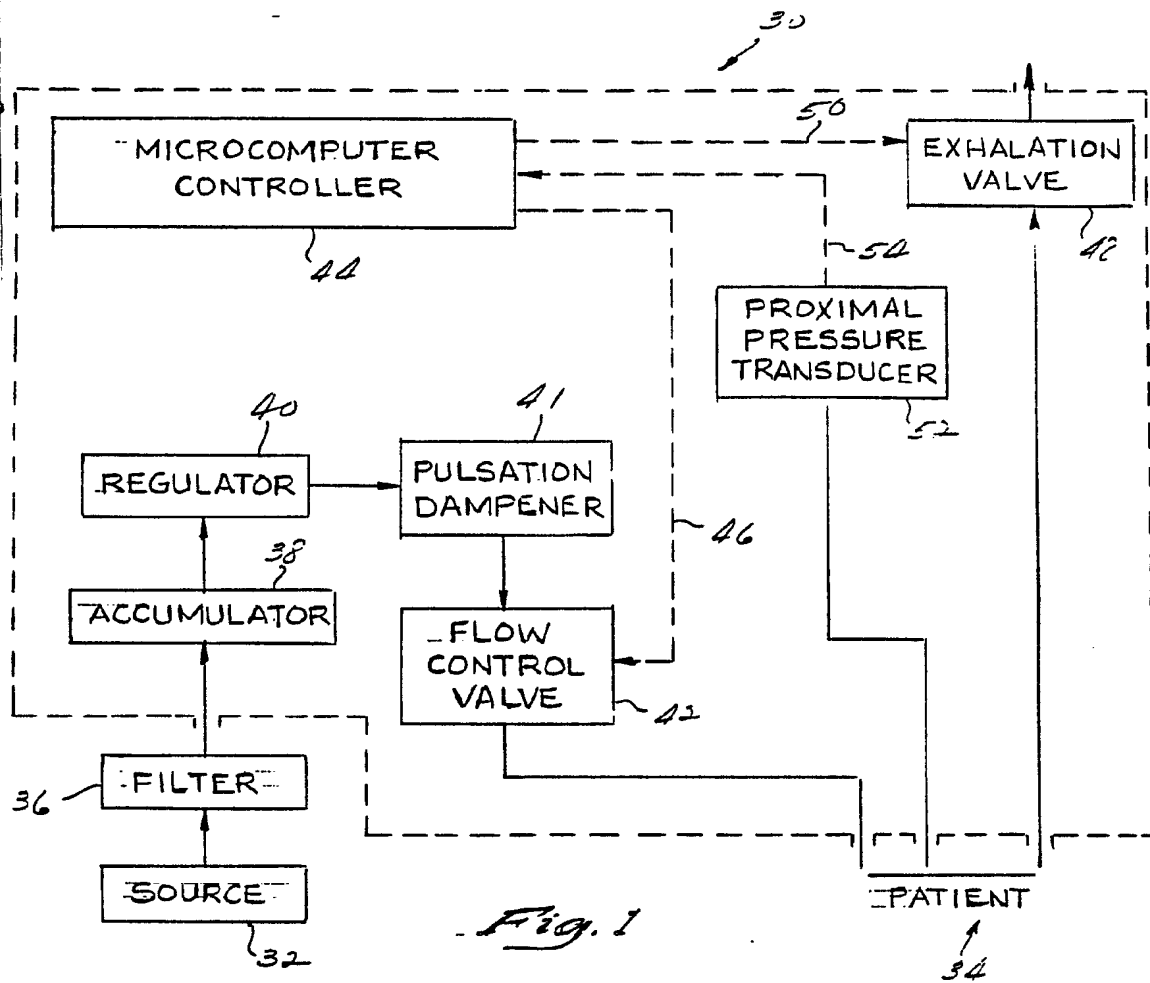


Fig. 2

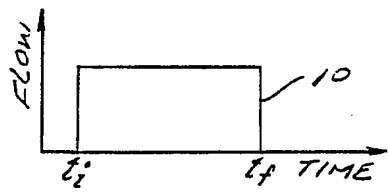


Fig. 3a

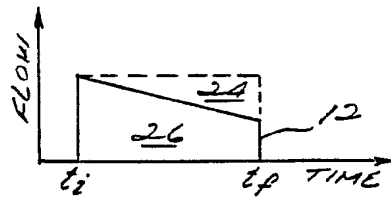


Fig. 3b

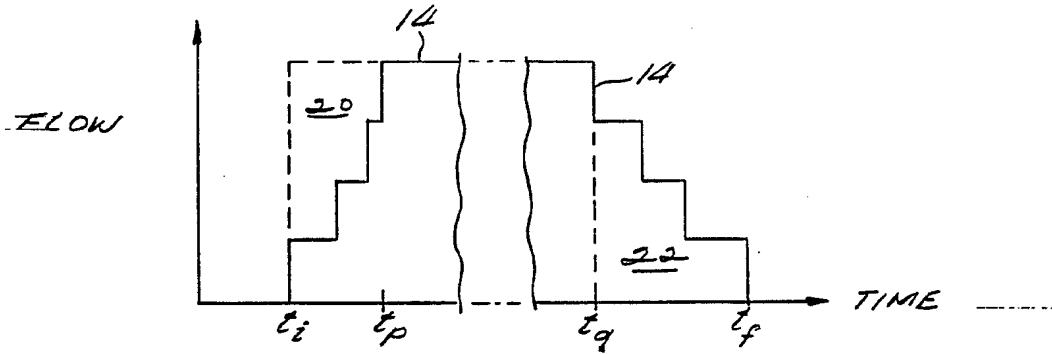


Fig. 4

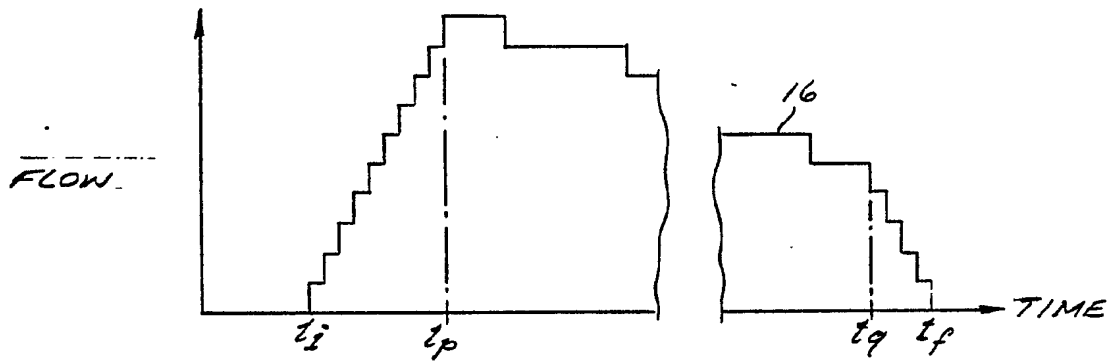


Fig. 5

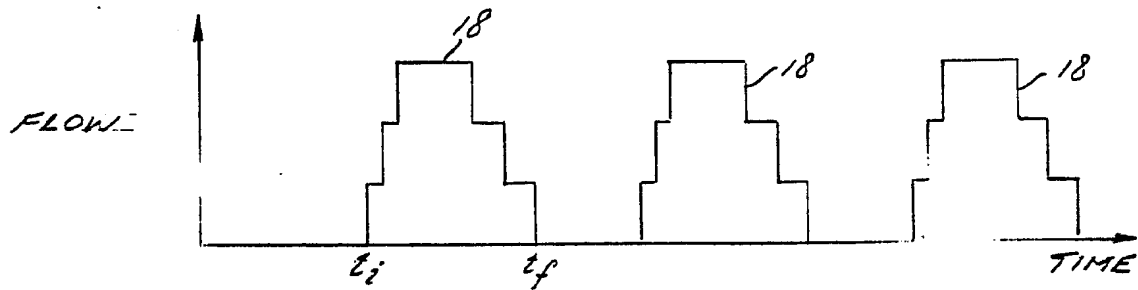


Fig. 6

Neu eingetragt / Newly filed
Nouvellement déposé

APPENDIX -A-

AVOCET SYSTEMS 8051 CROSS-ASSEMBLER - VERSION 1.10M

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List File: 6400PWR.PRN

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

; Flow Control Valve Forward Acceleration Table 3 --
3000 steps/sec
;

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-----
1500          FCVFAT3:
1500 0000      DW          0
1502 00        DB          0
1503 FA6A      DW FCODECMP -(1441 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step

1505 B4        DB          (1441 + 4) / 8
1506 FD43      DW FCODECMP -(712 * FOSC / 12) ; 2
1508 59        DB          (712 + 4) / 8
1509 FDBB      DW FCODECMP -(592 * FOSC / 12) ; 3
150B 4A        DB          (592 + 4) / 8
150C FDF9      DW FCODECMP -(530 * FOSC / 12) ; 4
150E 42        DB          (530 + 4) / 8
150F FE20      DW FCODECMP -(491 * FOSC / 12) ; 5
1511 3D        DB          (491 + 4) / 8
1512 FE3B      DW FCODECMP -(464 * FOSC / 12) ; 6
1514 3A        DB          (464 + 4) / 8
1515 FE50      DW FCODECMP -(443 * FOSC / 12) ; 7
1517 37        DB          (443 + 4) / 8
1518 FE61      DW FCODECMP -(426 * FOSC / 12) ; 8
151A 35        DB          (426 + 4) / 8
151B FE6E      DW FCODECMP -(413 * FOSC / 12) ; 9
151D 34        DB          (413 + 4) / 8
151E FE7A      DW FCODECMP -(401 * FOSC / 12) ; 10
1520 32        DB          (401 + 4) / 8
1521 FE83      DW FCODECMP -(392 * FOSC / 12) ; 11
1523 31        DB          (392 + 4) / 8
1524 FE8C      DW FCODECMP -(383 * FOSC / 12) ; 12
1526 30        DB          (383 + 4) / 8
1527 FE93      DW FCODECMP -(376 * FOSC / 12) ; 13
1529 2F        DB          (376 + 4) / 8
152A FE99      DW FCODECMP -(370 * FOSC / 12) ; 14
152C 2E        DB          (370 + 4) / 8
152D FE9E      DW FCODECMP -(365 * FOSC / 12) ; 15
152F 2E        DB          (365 + 4) / 8
1530 FEA3      DW FCODECMP -(360 * FOSC / 12) ; 16
1532 2D        DB          (360 + 4) / 8
1533 FEA8      DW FCODECMP -(355 * FOSC / 12) ; 17
1535 2C        DB          (355 + 4) / 8
1536 FEAB      DW FCODECMP -(352 * FOSC / 12) ; 18
1538 2C        DB          (352 + 4) / 8
1539 FEAF      DW FCODECMP -(348 * FOSC / 12) ; 19
153B 2C        DB          (348 + 4) / 8
153C FEB2      DW FCODECMP -(345 * FOSC / 12) ; 20
153E 2B        DB          (345 + 4) / 8
153F FEB5      DW FCODECMP -(342 * FOSC / 12) ; 21
1541 2B        DB          (342 + 4) / 8
1542 FEB7      DW FCODECMP -(340 * FOSC / 12) ; 22
1544 2B        DB          (340 + 4) / 8
1545 FEBA      DW FCODECMP -(337 * FOSC / 12) ; 23

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REV. 9/18/86
 NEWELL 311 66780

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

1547 2A	DB	(337 + 4) / 8	
1548 FEBC	DW	FCODECMP - (335 * FOSC / 12)	; 24
154A 2A	DB	(335 + 4) / 8	
154B FEBA	DW	FCODECMP - (337 * FOSC / 12)	; 25
154D 2A	DB	(337 + 4) / 8	
154E FEBA	DW	FCODECMP - (337 * FOSC / 12)	; 26th time delay until next half step
1550 2A	DB	(337 + 4) / 8	
1551 FEBE	DW	FCODECMP - (333 * FOSC / 12)	; 27
1553 2A	DB	(333 + 4) / 8	
1554 FEBE	DW	FCODECMP - (333 * FOSC / 12)	; 28
1556 2A	DB	(333 + 4) / 8	
1557 FEBE	DW	FCODECMP - (333 * FOSC / 12)	; 29
1559 2A	DB	(333 + 4) / 8	
155A FEBE	DW	FCODECMP - (333 * FOSC / 12)	; 30
155C 2A	DB	(333 + 4) / 8	
155D FEBE	DW	FCODECMP - (333 * FOSC / 12)	; 31
155F 2A	DB	(333 + 4)	

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

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;      Flow Control Valve Forward Acceleration Table 2 --
;      2000 steps/sec
;

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-----
1560      FCVFAT2:
1560 0000      DW 0
1562 00      DB 0
1563 FA2B      DW FCODECMP -(1504 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step
1565 BC      DB
1566 FD30      DW FCODECMP -(1504 + 4) / 8
1568 5B      DB FCODECMP -(731 * FOSC / 12) ; 2
1569 FCBE      DW FCODECMP -(731 + 4) / 8
156B 6A      DB FCODECMP -(845 * FOSC / 12) ; 3
156C Fddb      DW FCODECMP -(845 + 4) / 8
156E 46      DB FCODECMP -(560 * FOSC / 12) ; 4
156F FDDD      DW FCODECMP -(560 + 4) / 8
1571 46      DB FCODECMP -(558 * FOSC / 12) ; 5
1572 FDD9      DW FCODECMP -(558 + 4) / 8
                                         6th time delay
                                         until next half
                                         step
1574 46      DB FCODECMP -(562 + 4) / 8
1575 FE17      DW FCODECMP -(500 * FOSC / 12) ; 7
1577 3F      DB FCODECMP -(500 + 4) / 8
1578 FE17      DW FCODECMP -(500 * FOSC / 12) ; 8
157A 3F      DB FCODECMP -(500 + 4) / 8
157B FE17      DW FCODECMP -(500 * FOSC / 12) ; 9
157D 3F      DB FCODECMP -(500 + 4) / 8
157E FE17      DW FCODECMP -(500 * FOSC / 12) ; 10
1580 3F      DB FCODECMP -(500 + 4) / 8

```

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;      Flow Control Valve Forward Acceleration Table 1 --
;      1250 steps/sec
;

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```

-----
1581      FCVFAT1:
1581 0000      DW 0
1583 00      DB 0
1584 F933      DW FCODECMP -(1752 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step
1586 DB      DB
1587 FB57      DW FCODECMP -(1752 + 4) / 8
                                         2nd time delay
                                         until next half
                                         step
1589 97      DB FCODECMP -(1204 * FOSC / 12) ; 3
158A FCEB      DW FCODECMP -(1204 + 4) / 8
158C 64      DB FCODECMP -(800 * FOSC / 12) ; 4
158D FCEB      DW FCODECMP -(800 + 4) / 8
158F 64      DB FCODECMP -(800 * FOSC / 12) ; 5
1590 FCEB      DW FCODECMP -(800 + 4) / 8
1592 64      DB FCODECMP -(800 * FOSC / 12) ; 6
1593 FCEB      DW FCODECMP -(800 + 4) / 8
1595 64      DB FCODECMP -(800 * FOSC / 12) ; 7
1596 FCEB      DW FCODECMP -(800 + 4) / 8
1598 64      DB FCODECMP -(800 + 4) / 8

```

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

; Flow Control Valve Forward Deceleration Table 2 --
 2000 steps/sec

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-----
15C9          FCVFDT2:
15C9 FE17      DW FCODECMP -(500 * FOSC / 12) ; 0 half steps from
                destination
15CB 3F        DB          (500 + 4) / 8
15CC FAFA      DW FCODECMP -(1297 * FOSC / 12) ; 1 half steps from
                destination
15CE A2        DB          (1297 + 4) / 8
15CF FC6E      DW FCODECMP -(925 * FOSC / 12) ; 2 half steps from
                destination
15D1 74        DB          (925 + 4) / 8
15D2 FCD7      DW FCODECMP -(820 * FOSC / 12) ; 3 half steps from
                destination
15D4 67        DB          (820 + 4) / 8
15D5 FE17      DW FCODECMP -(500 * FOSC / 12) ; 4 half steps from
                destination
15D7 3F        DB          (500 + 4) / 8
15D8 FE17      DW FCODECMP -(500 * FOSC / 12) ; 5
15DA 3F        DB          (500 + 4) / 8
15DB FE17      DW FCODECMP -(500 * FOSC / 12) ; 6
15DD 3F        DB          (500 + 4) / 8
15DE FE17      DW FCODECMP -(500 * FOSC / 12) ; 7
15E0 3F        DB          (500 + 4) / 8
  
```

; Flow Control Valve Forward Deceleration Table 1 --
 1250 steps/sec

```

-----
15E1          FCVFDT1:
15E1 FCEB      DW FCODECMP -(800 * FOSC / 12) ; 0 half steps from
                destination
15E3 64        DB          (800 + 4) / 8
15E4 F8BA      DW FCODECMP -(1873 * FOSC / 12) ; 1 half steps from
                destination
15E6 EA        DB          (1873 + 4) / 8
15E7 FC69      DW FCODECMP -(930 * FOSC / 12) ; 2 half steps from
                destination
15E9 74        DB          (930 + 4) / 8
15EA FCEB      DW FCODECMP -(800 * FOSC / 12) ; 3 half steps from
                destination
15EC 64        DB          (800 + 4) / 8
15ED FCEB      DW FCODECMP -(800 * FOSC / 12) ; 4 half steps from
                destination
15EF 64        DB          (800 + 4) / 8
15F0 FCEB      DW FCODECMP -(800 * FOSC / 12) ; 5
15F2 64        DB          (800 + 4) / 8
15F3 FCEB      DW FCODECMP -(800 * FOSC / 12) ; 6
15F5 64        DB          (800 + 4) / 8
15F6 FCEB      DW FCODECMP -(800 * FOSC / 12) ; 7
15F8 64        DB          (800 + 4) / 8
  
```

Neu eingereicht / Newly filed Nouvellement déposé

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List File: 6400PWR.PRN

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Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

```

      ;      Special Case - 10 steps Forward
      ;      -----
16EC      FGVFT10:
16EC 0000      DW 0
16EE 00      DB 0
16EF F933      DW FCODECMP -(1752 * FOSC / 12) ; 1st time delay
                                          after first half
                                          step and before
                                          second half step

16F1 DB      DB      (1752 + 4) / 8
16F2 FBA5      DW FCODECMP -(1126 * FOSC / 12) ; 2nd time delay
                                          after second half
                                          step and before
                                          third half step

16F4 8D      DB      (1126 + 4) / 8
16F5 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 3rd time delay
                                          after third half
                                          step and before
                                          forth half step

16F7 64      DB      ( 800 + 4) / 8
16F8 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 4th time delay
                                          after forth half
                                          step and before
                                          fifth half step

16FA 64      DB      ( 800 + 4) / 8
16FB FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 5th time delay
                                          after fifth half
                                          step and before
                                          sixth half step

16FD 64      DB      ( 800 + 4) / 8
16FE FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 6th time delay
                                          after sixth half
                                          step and before
                                          seventh half step

1700 64      DB      ( 800 + 4) / 8
1701 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 7th time delay
                                          after seventh half
                                          step and before
                                          eighth half step

1703 64      DB      ( 800 + 4) / 8
1704 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 8th time delay
                                          after eighth half
                                          step and before
                                          ninth half step

1706 64      DB      ( 800 + 4) / 8
1707 F83E      DW FCODECMP -(1997 * FOSC / 12) ; 9th time delay
                                          after ninth half
                                          step and before
                                          final half step

1709 FA      DB      (1997 + 4) / 8

```

Neu eingereicht / Newly filed
Nouvellement déposé

Special Case - 8 steps Forward

```

;
; FCVFT8:
170A      DW 0
170A 0000 DB 0
170C 00   DW FCODECMP -(1498 * FOSC / 12) ; 1st time delay
170D FA31                                     after first half
                                                step and before
                                                second half step

170F BB    DB
1710 FC57  DW FCODECMP -( (1498 + 4) / 8
                        - { 948 * FOSC / 12 } ; 2nd time delay
                                                after second half
                                                step and before
                                                third half step

1712 77    DB
1713 FCEB  DW FCODECMP -( ( 948 + 4) / 8
                        - { 800 * FOSC / 12 } ; 3rd time delay
                                                after third half
                                                step and before
                                                forth half step

1715 64    DB
1716 FCEB  DW FCODECMP -( ( 800 + 4) / 8
                        - { 800 * FOSC / 12 } ; 4th time delay
                                                after forth half
                                                step and before
                                                fifth half step

1718 64    DB
1719 FCEB  DW FCODECMP -( ( 800 + 4) / 8
                        - { 800 * FOSC / 12 } ; 5th time delay
                                                after fifth half
                                                step and before
                                                sixth half step

171B 64    DB
171C FD67  DW FCODECMP -( ( 800 + 4) / 8
                        - { 676 * FOSC / 12 } ; 6th time delay
                                                after sixth half
                                                step and before
                                                seventh half step

171E 55    DB
171F F8BC  DW FCODECMP -( ( 676 + 4) / 8
                        - { 1871 * FOSC / 12 } ; 7th time delay
                                                after seventh half
                                                step and before
                                                eighth half step

1721 EA    DB          (1871 + 4) / 8

```

New original / Newly filed
Nouvellement déposé

AVOCET SYSTEMS 8051 CROSS-ASSEMBLER - VERSION 1.10M

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October 28, 1986

List File: 6400PWR.PRN

Source File Name: 6400FTb1.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

```

;      Special Case - 6 steps Forward
;      -----
1722      FCVFT6:
1722 0000      DW 0
1724 00      DB 0
1725 FA31      DW FCODECMP -(1498 * FOSC / 12) ; 1st time delay
                                                after first half
                                                step and before
                                                second half step

1727 BB      DB
1728 FC57      DW FCODECMP -(1498 + 4) / 8
                                                (948 * FOSC / 12) ; 2nd time delay
                                                after second half
                                                step and before
                                                third half step

172A 77      DB
172B FCEB      DW FCODECMP -(948 + 4) / 8
                                                (800 * FOSC / 12) ; 3rd time delay
                                                after third half
                                                step and before
                                                forth half step

172D 64      DB
172E FBC7      DW FCODECMP -(800 + 4) / 8
                                                (1092 * FOSC / 12) ; 4th time delay
                                                after forth half
                                                step and before
                                                fifth half step

1730 89      DB
1731 F9BE      DW FCODECMP -(1092 + 4) / 8
                                                (1613 * FOSC / 12) ; 5th time delay
                                                after fifth half
                                                step and before
                                                final half step

1733 CA      DB
                                                (1613 + 4) / 8

;      Special Case - 4 steps Forward
;      -----
1734 0000      FCVFT4: DW 0
1736 00      DB 0
1737 F97E      DW FCODECMP -(1677 * FOSC / 12) ; 1st time delay
                                                after first half
                                                step and before
                                                second half step

1739 D2      DB
173A FBE7      DW FCODECMP -(1677 + 4) / 8
                                                (1060 * FOSC / 12) ; 2nd time delay
                                                after second half
                                                step and before
                                                third half step

173C 85      DB
173D F813      DW FCODECMP -(1060 + 4) / 8
                                                (2040 * FOSC / 12) ; 3rd time delay
                                                after third half
                                                step and before
                                                final half step

173F FF      DB
                                                (2040 + 4) / 8

```

•
•
•
•

```
FCVFT2: DW 0
         DB 0
         DW FCODECMP - (1999 * FOSC / 12) ; 1st time delay
                                                after first fwd
                                                half step and
                                                before the rev half
                                                step
         DB
         DW FCODECMP - (1999 + 4) / 8
         DW FCODECMP - (461 * FOSC / 12) ; 2nd time delay
                                                after the rev half
                                                step and before
                                                second fwd half
                                                step
         DB
         DW FCODECMP - (461 + 4) / 8
         DW FCODECMP - (973 * FOSC / 12) ; 3rd time delay
                                                after second half
                                                step and before the
                                                final fwd half step
         DB
         DW FCODECMP - (973 + 4) / 8
```

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

```

;          Flow Control Valve Reverse Acceleration Table 3 --
;          3000 steps/sec
;
-----
15F9          FCVRAT3:
15F9 0000      DW 0
15FB 00        DB 0
15FC FBC8      DW FCODECMP -(1091 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step
15FE 88        DB          (1091 + 4) / 8
15FF FD8E      DW FCODECMP -(637 * FOSC / 12) ; 2nd time delay
                                         until next half
                                         step
1601 50        DB          (637 + 4) / 8
1602 FE2B      DW FCODECMP -(480 * FOSC / 12) ; 3rd time delay
                                         until next half
                                         step
1604 3C        DB          (480 + 4) / 8
1605 FE6F      DW FCODECMP -(412 * FOSC / 12) ; 4th time delay
                                         until next half
                                         step
1607 34        DB          (412 + 4) / 8
1608 FDFE      DW FCODECMP -(525 * FOSC / 12) ; 5th time delay
                                         until next half
                                         step
160A 42        DB          (525 + 4) / 8
160B FDFE      DW FCODECMP -(525 * FOSC / 12) ; 6th time delay
                                         until next half
                                         step
160D 42        DB          (525 + 4) / 8
160E FEBE      DW FCODECMP -(333 * FOSC / 12) ;
1610 2A        DB          (333 + 4) / 8
1611 FEBE      DW FCODECMP -(333 * FOSC / 12) ;
1613 2A        DB          (333 + 4) / 8

```


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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

; Flow Control Valve Reverse Acceleration Table 2 --
2000 steps/sec
;

```
-----
1614 FCVRAT2:
1614 0000 DW 0
1616 00 DB 0
1617 FC54 DW FCODECMP -(951 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step
1619 77 DB (951 + 4) / 8
161A FC55 DW FCODECMP -(950 * FOSC / 12) ; 2
161C 77 DB (950 + 4) / 8
161D FCAF DW FCODECMP -(860 * FOSC / 12) ; 3
161F 6C DB (860 + 4) / 8
1620 FE17 DW FCODECMP -(500 * FOSC / 12) ; 4
1622 3F DB (500 + 4) / 8
1623 FE17 DW FCODECMP -(500 * FOSC / 12) ; 5
1625 3F DB (500 + 4) / 8
1626 FE17 DW FCODECMP -(500 * FOSC / 12) ; 6
1628 3F DB (500 + 4) / 8
1629 FE17 DW FCODECMP -(500 * FOSC / 12) ; 7
162B 3F DB (500 + 4) / 8
```

; Flow Control Valve Reverse Acceleration Table 1 --
1250 steps/sec
;

```
-----
162C FCVRAT1:
162C 0000 DW 0
162E 00 DB 0
162F FA7E DW FCODECMP -(1421 * FOSC / 12) ; 1st time delay
                                         until next half
                                         step
1631 B2 DB (1421 + 4) / 8
1632 FC8A DW FCODECMP -(897 * FOSC / 12) ; 2
1634 70 DB (897 + 4) / 8
1635 FCEB DW FCODECMP -(800 * FOSC / 12) ; 3
1637 64 DB (800 + 4) / 8
1638 FCEB DW FCODECMP -(800 * FOSC / 12) ; 4
163A 64 DB (800 + 4) / 8
163B FCEB DW FCODECMP -(800 * FOSC / 12) ; 5
163D 64 DB (800 + 4) / 8
163E FCEB DW FCODECMP -(800 * FOSC / 12) ; 6
1640 64 DB (800 + 4) / 8
1641 FCEB DW FCODECMP -(800 * FOSC / 12) ; 7
1643 64 DB (800 + 4) / 8
```

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

; Flow Control Valve Reverse Deceleration Table 3 --
 3000 steps/sec
 ;

```

-----
1644 FCVRDT3:
1644 FEBE DW FCODECMP -(333 * FOSC / 12) ; 0 half steps from
          destination
1646 2A DB (333 + 4) / 8
1647 FB3E DW FCODECMP -(1229 * FOSC / 12) ; 1
1649 9A DB (1229 + 4) / 8
164A FBFE DW FCODECMP -(1037 * FOSC / 12) ; 2
164C 82 DB (1037 + 4) / 8
164D FDEE DW FCODECMP -(541 * FOSC / 12) ; 3
164F 44 DB (541 + 4) / 8
1650 FE28 DW FCODECMP -(483 * FOSC / 12) ; 4
1652 3C DB (483 + 4) / 8
1653 FE4E DW FCODECMP -(445 * FOSC / 12) ; 5
1655 38 DB (445 + 4) / 8
1656 FE69 DW FCODECMP -(418 * FOSC / 12) ; 6
1658 34 DB (418 + 4) / 8
1659 FE7E DW FCODECMP -(397 * FOSC / 12) ; 7
165B 32 DB (397 + 4) / 8
165C FE8E DW FCODECMP -(381 * FOSC / 12) ; 8
165E 30 DB (381 + 4) / 8
165F FE9C DW FCODECMP -(367 * FOSC / 12) ; 9
1661 2E DB (367 + 4) / 8
1662 FEA7 DW FCODECMP -(356 * FOSC / 12) ; 10
1664 2D DB (356 + 4) / 8
1665 FEB0 DW FCODECMP -(347 * FOSC / 12) ; 11
1667 2B DB (347 + 4) / 8
1668 FEAE DW FCODECMP -(349 * FOSC / 12) ; 12
166A 2C DB (349 + 4) / 8
166B FEAE DW FCODECMP -(349 * FOSC / 12) ; 13
166D 2C DB (349 + 4) / 8
166E FEBE DW FCODECMP -(333 * FOSC / 12) ; 14
1670 2A DB (333 + 4) / 8
1671 FEBE DW FCODECMP -(333 * FOSC / 12) ; 15 half steps from
          destination
1673 2A DB (333 + 4) / 8
1674 FEBE DW FCODECMP -(333 * FOSC / 12) ; 16
1676 2A DB (333 + 4) / 8
1677 FEBE DW FCODECMP -(333 * FOSC / 12) ; 17
1679 2A DB (333 + 4) / 8
167A FEBE DW FCODECMP -(333 * FOSC / 12) ; 18
167C 2A DB (333 + 4) / 8
167D FEBE DW FCODECMP -(333 * FOSC / 12) ; 19
167F 2A DB (333 + 4) / 8
1680 FEBE DW FCODECMP -(333 * FOSC / 12) ; 20
1682 2A DB (333 + 4) / 8
1683 FEBE DW FCODECMP -(333 * FOSC / 12) ; 21
1685 2A DB (333 + 4) / 8
1686 FEBE DW FCODECMP -(333 * FOSC / 12) ; 22
1688 2A DB (333 + 4) / 8
1689 FEBE DW FCODECMP -(333 * FOSC / 12) ; 23

```

AVOGET SYSTEMS 8051 CROSS-ASSEMBLER - VERSION 1.10M

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

168B 2A	DB	(333 + 4) / 8	
168C FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 24
168E 2A	DB	(333 + 4) / 8	
168F FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 25
1691 2A	DB	(333 + 4) / 8	
1692 FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 26
1694 2A	DB	(333 + 4) / 8	
1695 FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 27
1697 2A	DB	(333 + 4) / 8	
1698 FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 28
169A 2A	DB	(333 + 4) / 8	
169B FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 29
169D 2A	DB	(333 + 4) / 8	
169E FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 30
16A0 2A	DB	(333 + 4) / 8	
16A1 FEBE	DW FCODECMP	-(333 * FOSC / 12)	; 31
16A3 2A	DB	(333 + 4) / 8	

Neu eingeleicht / Newly filed
Nouvellement déposé

AVOCET SYSTEMS 8051 CROSS-ASSEMBLER - VERSION 1.10M

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

; Flow Control Valve Reverse Deceleration Table 2 --
2000 steps/sec
;

```
-----
16A4 FCVRDT2:
16A4 FE17 DW FCODECMP -(500 * FOSC / 12) ; 0 half steps from
          DB (500 + 4) / 8 destination
16A6 3F DB (500 + 4) / 8
16A7 FA88 DW FCODECMP -(1411 * FOSC / 12) ; 1
16A9 B0 DB (1411 + 4) / 8
16AA FD13 DW FCODECMP -(760 * FOSC / 12) ; 2
16AC 5F DB (760 + 4) / 8
16AD FDCE DW FCODECMP -(573 * FOSC / 12) ; 3
16AF 48 DB (573 + 4) / 8
16B0 FD78 DW FCODECMP -(659 * FOSC / 12) ; 4
16B2 52 DB (659 + 4) / 8
16B3 FE17 DW FCODECMP -(500 * FOSC / 12) ; 5
16B5 3F DB (500 + 4) / 8
16B6 FE17 DW FCODECMP -(500 * FOSC / 12) ; 6
16B8 3F DB (500 + 4) / 8
16B9 FE17 DW FCODECMP -(500 * FOSC / 12) ; 7
16BB 3F DB (500 + 4) / 8
16BC FE17 DW FCODECMP -(500 * FOSC / 12) ; 8
16BE 3F DB (500 + 4) / 8
16BF FE17 DW FCODECMP -(500 * FOSC / 12) ; 9
16C1 3F DB (500 + 4) / 8
16C2 FE17 DW FCODECMP -(500 * FOSC / 12) ; 10
16C4 3F DB (500 + 4) / 8
16C5 FE17 DW FCODECMP -(500 * FOSC / 12) ; 11
16C7 3F DB (500 + 4) / 8
16C8 FE17 DW FCODECMP -(500 * FOSC / 12) ; 12
16CA 3F DB (500 + 4) / 8
16CB FE17 DW FCODECMP -(500 * FOSC / 12) ; 13
16CD 3F DB (500 + 4) / 8
16CE FE17 DW FCODECMP -(500 * FOSC / 12) ; 14
16D0 3F DB (500 + 4) / 8
16D1 FE17 DW FCODECMP -(500 * FOSC / 12) ; 15 half steps from
          DB (500 + 4) / 8 destination
16D3 3F DB (500 + 4) / 8
```

; Flow Control Valve Reverse Deceleration Table 1 --
1250 steps/sec
;

```
-----
16D4 FCVRDT1:
16D4 FCEB DW FCODECMP -(800 * FOSC / 12) ; 0 half steps from
          DB (800 + 4) / 8 destination
16D6 64 DB (800 + 4) / 8
16D7 F970 DW FCODECMP -(1691 * FOSC / 12) ; 1
16D9 D3 DB (1691 + 4) / 8
16DA FD1C DW FCODECMP -(751 * FOSC / 12) ; 2
16DC 5E DB (751 + 4) / 8
16DD FCEB DW FCODECMP -(800 * FOSC / 12) ; 3
16DF 64 DB (800 + 4) / 8
16E0 FCEB DW FCODECMP -(800 * FOSC / 12) ; 4
16E2 64 DB (800 + 4) / 8
```

Neu eingereicht / New, filed
Nouvellement déposé

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

16E3 FCEB	DW FCODECMP	-(800 * FOSC / 12)	; 5
16E5 64	DB	(800 + 4) / 8	
16E6 FCEB	DW FCODECMP	-(800 * FOSC / 12)	; 6
16E8 64	DB	(800 + 4) / 8	
16E9 FCEB	DW FCODECMP	-(800 * FOSC / 12)	; 7
16EB 64	DB	(800 + 4) / 8	

Nouveau brevet / New Invention
 Nouveau brevet déposé

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List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

```

;      Special Case - 10 steps Reverse
;      -----
174C      FCVRT10:
174C 0000      DW 0
174E 00      DB 0
174F F9FE      DW FCODECMP -(1549 * FOSC / 12) ; 1st time delay
                                           after first half
                                           step and before
                                           second half step

1751 C2      DB (1549 + 4) / 8
1752 FBA5      DW FCODECMP -(1126 * FOSC / 12) ; 2nd time delay
                                           after second half
                                           step and before
                                           third half step

1754 8D      DB (1126 + 4) / 8
1755 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 3rd time delay
                                           after third half
                                           step and before
                                           forth half step

1757 64      DB ( 800 + 4) / 8
1758 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 4th time delay
                                           after forth half
                                           step and before
                                           fifth half step

175A 64      DB ( 800 + 4) / 8
175B FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 5th time delay
                                           after fifth half
                                           step and before
                                           sixth half step

175D 64      DB ( 800 + 4) / 8
175E FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 6th time delay
                                           after sixth half
                                           step and before
                                           seventh half step

1760 64      DB ( 800 + 4) / 8
1761 FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 7th time delay
                                           after seventh half
                                           step and before
                                           eighth half step

1763 64      DB ( 800 + 4) / 8
1764 FC3E      DW FCODECMP -( 973 * FOSC / 12) ; 8th time delay
                                           after eighth half
                                           step and before
                                           ninth half step

1766 7A      DB ( 973 + 4) / 8
1767 F87E      DW FCODECMP -(1933 * FOSC / 12) ; 9th time delay
                                           after ninth half
                                           step and before
                                           final half step

1769 F2      DB (1933 + 4) / 8
  
```

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 SECURITY INFORMATION
 NO FORN DISSEM

Special Case - 8 steps Reverse

```

;
;
FCVRT8:
176A      DW 0
176A 0000 DB 0
176C 00
176D FA7E DW FCODECMP -(1421 * FOSC / 12) ; 1st time delay
                                                after first half
                                                step and before
                                                second half step

176F B2    DB (1421 + 4) / 8
1770 FC8A DW FCODECMP -( 897 * FOSC / 12) ; 2nd time delay
                                                after second half
                                                step and before
                                                third half step

1772 70    DB ( 897 + 4) / 8
1773 FCEB DW FCODECMP -( 800 * FOSC / 12) ; 3rd time delay
                                                after third half
                                                step and before
                                                forth half step

1775 64    DB ( 800 + 4) / 8
1776 FCEB DW FCODECMP -( 800 * FOSC / 12) ; 4th time delay
                                                after forth half
                                                step and before
                                                fifth half step

1778 64    DB ( 800 + 4) / 8
1779 FCEB DW FCODECMP -( 800 * FOSC / 12) ; 5th time delay
                                                after fifth half
                                                step and before
                                                sixth half step

177B 64    DB ( 800 + 4) / 8
177C FD9A DW FCODECMP -( 625 * FOSC / 12) ; 6th time delay
                                                after sixth half
                                                step and before
                                                seventh half step

177E 4E    DB ( 625 + 4) / 8
177F F86E DW FCODECMP -(1949 * FOSC / 12) ; 7th time delay
                                                after seventh half
                                                step and before
                                                eighth half step

1781 F4    DB (1949 + 4) / 8

```

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 October 28, 1986
 List File: 6400PWR.PRN
 Source File Name: 6400FTbl.SRC
 Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

AVOCET SYSTEMS 8051 CROSS-ASSEMBLER - VERSION 1.10M

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 October 28, 1986

List File: 6400PWR.PRN

Source File Name: 6400FTbl.SRC

Flow Control Valve Acceleration/Deceleration Tables Rev. 9/18/86

```

;      Special Case - 6 steps Reverse
;      -----
1782      FCVRT6:
1782 0000      DW 0
1784 00      DB 0
1785 F97E      DW FCODECMP -(1677 * FOSC / 12) ; 1st time delay
;                                     after first half
;                                     step and before
;                                     second half step

1787 D2      DB      (1677 + 4) / 8
1788 FC8A      DW FCODECMP -( 897 * FOSC / 12) ; 2nd time delay
;                                     after second half
;                                     step and before
;                                     third half step

178A 70      DB      ( 897 + 4) / 8
178B FCEB      DW FCODECMP -( 800 * FOSC / 12) ; 3rd time delay
;                                     after third half
;                                     step and before
;                                     forth half step

178D 64      DB      ( 800 + 4) / 8
178E FB8B      DW FCODECMP -(1152 * FOSC / 12) ; 4th time delay
;                                     after forth half
;                                     step and before
;                                     fifth half step

1790 90      DB      (1152 + 4) / 8
1791 F970      DW FCODECMP -(1691 * FOSC / 12) ; 5th time delay
;                                     after fifth half
;                                     step and before
;                                     final half step

1793 D3      DB      (1691 + 4) / 8

;      Special Case - 4 steps Reverse
;      -----
1794 0000      FCVRT4: DW 0
1796 00      DB 0
1797 F8FE      DW FCODECMP -(1805 * FOSC / 12) ; 1st time delay
;                                     after first half
;                                     step and before
;                                     second half step

1799 E2      DB      (1805 + 4) / 8
179A FBA7      DW FCODECMP -(1124 * FOSC / 12) ; 2nd time delay
;                                     after second half
;                                     step and before
;                                     third half step

179C 8D      DB      (1124 + 4) / 8
179D F87E      DW FCODECMP -(1933 * FOSC / 12) ; 3rd time delay
;                                     after third half
;                                     step and before
;                                     final half step

179F F2      DB      (1933 + 4) / 8

```


Special Case - 2 steps Reverse

17A0 0000
17A2 00
17A3 F9AE

FCVRT2: DW 0
DB 0
DW FCODECMP $-(1629 * FOSC / 12)$; 1st time delay
after first rev
half step and
before second rev
half step

17A5 CC
17A6 FF3E

DB $(1629 + 4) / 8$
DW FCODECMP $-(205 * FOSC / 12)$; 2nd time delay
after second rev
half step and
before the fwd half
step

17A8 1A
17A9 FABE

DB $(205 + 4) / 8$
DW FCODECMP $-(1357 * FOSC / 12)$; 3rd time delay
after the fwd half
step and before
final rev half step

17AB AA

DB $(1357 + 4) / 8$
END

2000

ORG 2000H
INCLUD 6400FXHL.SRC